

Final Research Report

to

National Aeronautics and Space Administration

Grant No. NGL-36-027-001

by

Case Western Reserve University

Cleveland, Ohio 44106

15 March 1973

CASE FILE COPY

The National Aeronautics and Space Administration (NASA) supported software design projects in the Department of Computing and Information Sciences and the Division of Computer Engineering at Case Western Reserve University in the amount of \$200,000 over a three-year period, 1 June 1969 to 31 May 1972. The funds were deployed in the areas of software design and, in particular, to the partial support of software design projects in connection with Project LOGOS (Computer-Aided Design and Certification of Computing Systems), sponsored by the Advanced Research Projects

Agency of the Department of Defense.

Copies of Project LOGOS Quarterly Management Reports to ARPA from 1 June 1969 to 31 August 1970 have been submitted, and Annual Reports for 1970-71 and 1971-72 are submitted herewith.

In addition, the following research theses, completed and still in progress, were supported in part by NASA funds:

M.S. Theses Completed

Bernard M. Elie, Bootstrapping of a BCPL Compiler for a PDP-10, June 1970.

Juliana S. Tu, A BCPL Library for CWRU PDP-10, January 1971.

Harold L. Pierson, A Testable Condition on Intersection of Context-Free Languages, January 1971.

Michel R. Parent, A Graphical Aid for the Study of Mathematical Functions, January 1971.

R. H. Wenning, Optimized Translation for LALR(1) Languages, June 1971, JCC Rep. 1110.

Cerard P. Huet, The Undecidability of the Existence of a Unifying Substitution between Two Terms in the Simple Theory of Types, September 1972, JCC Rep. 1120.

M.S. Thesis in Progress (working title)

Marshall J. Moore, Design and Implementation of the STEP-EDITOR System for PDP-10 LOGOS Designers.

Ph.D. Theses Completed

Howard B. Bandy, III, An Approach to Resource Allocation in a in a Computer-Communications Network, January 1972.

Linda D. Misek, Computing a Context: Style, Structure, Self-Image of Satan in Paradise Lost (English Dept.), January 1972, with companion publications, Automated Contextual Analysis of Thematic Structure in Natural Language, Jennings Comp. Center Rep. 1103 (1970) and Context Concordance to John Milton's Paradise Lost, Jennings Comp. Center Rep. 1111 (1972).

Timothy J. Zebo, Formant Analysis of Voiced Speech Based on the Method of Prony, July 1972.

Paul J. Jalics, Measurements of the PDP-10 TOPS-1 Operating System, January 1973.

Ph.D. Thesis in Progress (working title)

Celio Guimaraes, Mathematical Models of Computing System Performance.

Publications

The publications of faculty members partially supported by NASA funds during the grant period are listed, alphabetically by author:

Ranan B. Banerji: (with H. Bandy), A Study on Generalization Obtained by Pattern Recognition Algorithms, Proc. of 4th Ann. Princeton Conf. Info. Sci. and Sys., Princeton University, March 1970.

Machine Learning of Games, Parts I, II, Comp. and Autom. (Nov.-Dec. 1970).

Representation in Pattern Recognition and Problem Solving, Proc. 1970 Symp. on Adaptive Proc., Decision, and Control, IEEE, Austin, Tex. Dec. 1970.

Similarities in Games and Their Use in Strategy Construction, Symp. Theory of Comp., Brooklyn Polytech. Inst., N.Y., April 1970.

Simplicity of Concepts, Training, and the Real World, NATO Symp. Human Thinking--Computer Techniques for Its Evaluation (Elithorne & Jones, eds.), August 1971.

(with G.W. Ernst), Homomorphisms Which Preserve Strategies in Games, Proc. 2nd Int. J. Conf. Artif. Intel., London, 1971.

Some Linguistic and Statistical Problems in Pattern Recognition, Pattern Recogn., (Nov. 1971).

(with G.W. Ernst), Limitations in Pattern Recognition and Problem Solving, Proc. ACM Nat. Conf., Boston, 1972.

George W. Ernst: Decision-Making and GPS: An Overview, in THEORETICAL APPROACHES TO NON-NUMERICAL PROBLEM SOLVING (Banerji & Mesarovic, eds.) Springer-Verlag, N.Y., 1970.

(with D.S. Eavarone), A Program That Discovers Good Difference Orderings and Table of Connections for GPS, IEEE Syst. Sci. and Cyb. Conf. Rec., 1972.

The Utility of Independent Subgoals in Theorem Proving, Info. & Control, 18(3):237 (April 1971).

(with R.B. Banerji), Homomorphisms Which Preserve Strategies in Games, 2nd Int. J. Conf. Artif. Intel., London, 1971.

(with R.B. Banerji), Limitations in Pattern Recognition and Problem Solving, Proc. ACM Nat. Conf., Boston, 1972.

Edward L. Glaser: (with F. Way, III), The Computer as a Learning Machine, Institut de la Vie, Man and Computer Conf., Bordeaux, France, 1970.

Introduction and Overview of the LOGOS

Project, Compcon72, Digest, 175 (IEEE, 1972).

LOGOS--Where It Is Now and Where It Is Going, *ibid.*, 191.

(with F. Way, III), The Myth Is Dead -- Long Live the Myth, Invited Paper, 1972 Fall J. Comp. Conf., Anaheim, Cal., Dec. 1972.

Wen-Chun Lin:

(with M. Michael), Investigation of Two-Feature Evaluation Criteria, IEEE Int. Symp on Info. Theory, 1972.

(with T.J. Zabo), On the Accuracy of Formant Parameter Estimation Based on the Method of Prony, 1972 Int. Conf. on Speech Communication and Processing, IEEE, B10:85 (1972).

(with M. Michael), Experimental Study of Information Measure and Inter-Intra-Class Distance Ratio of Feature Selection and Orderings, IEEE Trans. on System, Man and Cybernetics, March 1973.

William C. Lynch: Operating System Performance, Coms. of ACM, 5(7):5719 (July 1972).

Operating Systems for a Computer Utility Environment and (with A. Alderson and B. Randell), Thrashing in a Multiprogrammed Paging System, in OPERATING SYSTEM TECHNIQUES (C.A.R. Hoare, ed.), Academic Press, New York and London, 1973.

William F. Ogden: (with W. C. Rounds), Compositions of N-Tree Transducers, Proc., 4th ACM Conf. on Theory of Computing, May 1972.

Gene F. Rose:

Abstract Families of Processors, J. Comp. and Syst. Sci. (June 1970).

(with S. Ginsburg), On the Existence of Generators for Certain AFL (published in 1972 but reference unknown, since Prof. Rose is

on leave in West Germany, 1972-73).

William C. Rounds: Context-Free Grammars on Trees, Proc. 1st ACM Symp., Theory of Computing, May 1969.

Context-Free and Indexed Languages, Proc. 2nd ACM Symp., Theory of Computing, May 1970.

Mappings and Grammars on Trees, Math. Syst. Theory (1971).

(with W. F. Ogden), Compositions of A-Tree Transducers, Proc. 4th ACM Conf. on Theory of Computing, May 1972.

Frederick Way, III: (with E.L. Glaser), The Computer as a Learning Machine, Institut de la Vie, Man and Computer Conf., Bordeaux, France, 1970.

UNIVAC 1108 FORTRAN V (ed. with F. Olynyk), Chi Corp., Cleveland, 1970.

SYSTEM PRIMER FOR CHI 1108 (ed.), Chi Corp. Cleveland, 1971.

EXTENDED ALGOL 6 (ed.), Chi Corp. Cleveland, 1971.

(with E.L. Glaser), The Myth Is Dead---Long Live the Myth, Invited Paper, 1972 Fall J. Comp. Conf. Anaheim, Cal., Dec. 1972.

Expenditures

A Contractor Financial Management Report -- Contracts under \$500,000 (NASA Form 533b Feb 67) dated 31 May 1972 was submitted on 25 Sept. 1972 by the Assistant Controller of the University detailing expenditures of \$200,000 as follows: direct labor, \$130,373; supplies, \$5,135; computer, \$5000; travel, \$2,000, and

indirect costs, \$57,492.

The University, by its Department of Computing and Information Sciences and Division of Computer Engineering, is ready to deliver copies of the foregoing theses and publications to NASA including documents mentioned in the Project LOGOS reports, as well as accounts in such detail as NASA may require.

Dated: 15 March 1973

*Edward L. Glaser*₁₅

Edward L. Glaser

Principal Investigator.

Project LOGOS Annual Report for 1 September 1971 to 30 August 1972

Sponsored by the Advanced Research Project Agency
of the Department of Defense

ARPA Order No.: 1372

Program Code No.: 9D20

Contractor: Case Western Reserve University, Cleveland, Ohio 44106

Effective Date: 15 May 1969

Expiration Date: 31 August 1972

Amount: \$2,000,200.00

Contract No.: DAAB 03-70-C0024

This annual report is in letter form as directed (ARPA,
Reporting Instructions, 22-13, p. 14) and is respectfully submitted:

E. L. Glaser

E. L. Glaser
Principal Investigator

October 10, 1972

The Director
Advanced Research Projects Agency
Department of Defense
1400 Wilson Blvd.
Arlington, VA. 22209

Annual Report, Project LOGOS 1971-72
Re: DAAB 03-70-C0024

Sir:

As directed I render this second annual report for 1971-72 in 15 copies under the above contract, full title of which is Computer-Aided Design and Certification of Computing Systems (Project LOGOS). This report covers the period from 1 September 1971 to 31 August 1972 for which the 9th through the 12th quarterly management reports were duly submitted.

A concise and factual discussion of technical findings and accomplishments for the report period follow:

1. The Primary Seminars on Project LOGOS were held October 27-28, 1971 for 57 representatives of the computer industry, universities, government agencies, and local faculty people at the University, then repeated for the sponsors on November 15, 1971. The Seminars were based on the following papers now published in Compcon 72, Digest of Papers, Innovative Architecture (IEEE, 1972):

E. L. Glaser, Introduction and Overview of the LOGOS Project, ibid., 175.

F. G. Heath and C. W. Rose, The Case for Integrated Hardware/Software Design, with CAD Implications, ibid., 179.

F. T. Bradshaw, Some Structural Ideas for Computer Systems, ibid., 183.

C. W. Rose, F. T. Bradshaw, and S. W. Katzke, The LOGOS Representation System, ibid., 187.

E. L. Glaser, LOGOS--Where It Is Now and Where It Is Going, ibid., 191.

Follow-up papers and articles were written during the report period and will be published in 1972-73.

2. A dissertation by Stuart W. Katzke, Graph-Oriented Data Structure Language was published, Case Western Reserve University, 1972. It established, for the LOGOS representation of data structures and the data transformations that take place on them, a syntactic formalism and semantics which allows designers to define the hardware and software data structures and data operators of the target system and define them as the designer wishes, under suitable constraints allowing mechanical and unambiguous implementation of the target system and various kinds of analysis, with guidelines for the implementation of the formalism. This implementation is progressing satisfactorily toward its September 1973 deadline.

3. The following improvements in the PDP-10 system, shown to be necessary by performance measurements, were made:

(a) A Tenex monitor system was installed. It was up and running with the fast drum on the PDP-10 in August.

(b) IMLAC terminals, interfaced with the PDP-10 pursuant to designs produced in a graphics environment of LOGOS representation and structural ideas, are up and running.

(c) Bootstrapping CHILI (Chi Implementation Language) from the Univac 1108 to the PDP-10 for the implementation of the LOGOS Languages (SAIL, LEAP) was undertaken and will be completed in October 1972.

4. The following progress with the LOGOS system is noted:

(a) Step Editor, the editing system for the LOGOS Display Package (LDP), is up and running, and integration with LDP began in the report year.

(b) Specifications for modular analysis packages for the representation system, block and layer organization and implementation, resource allocation, and deadlocks proceeded satisfactorily toward a September 1973 deadline.

(c) Specifications for the virtual LEAP system for the retrieval and manipulation of design information in the data bases were completed, and implementation is anticipated by March 1973.

(d) Specifications for a metagraphics language on the PDP-10 were virtually completed, which will allow National Security Agency people to make runs on the LOGOS system from their remote GT40 System.

(e) Plans for documentation for existing LOGOS software were formulated.

5. A reorganization of LOGOS tasks involving clear lines of responsibility in three areas of concentration for LOGOS programming

teams was accomplished. The areas are (1) the LDP (external representation, translators, internal representation including implementation of the Katzke formalisms, and data base creation), (2) work on the LEAP and data base constructs, and (3) the analysis packages. The work of the programming teams and their clearly understood missions now parallel the layered structure of the LOGOS system itself.

6. Explorations started during the report period on the LOGOS systems's interface with existing industrial CAD (computer-aided design) for the realization of LOGOS-designed hardware.

The following figures represent expenditures for the report year:

1. The amount funded was \$2,000,200.00.
2. The amount expended at the beginning of the report year, namely up to 31 August 1971, was \$989,196.64. Of this salaries were \$339,229.50, and nonsalary items were \$649,967.14.
3. The amount expended by the end of the report year, namely, 31 August 1972, was \$2,008,608.68. Of this, salaries were \$595,788.21, and nonsalary items were \$1,412,820.47.
4. An over-run of \$8,408.68, and approximately \$80,000 subject to negotiation, leaves a tentative deficit on the contract of \$88,406.68. Pending negotiations, this deficit is subtracted from funds under the renewal contract for 1 September 1972 to 30 April 1973 in the amount of \$550,000. The result of this action is that \$461,593.32 is available under the renewal contract.

By way of response to NSA needs and concerns, LOGOS job management and scheduling for 1973-74 has been restructured as noted above, and schedules stated in the Renewal Application of 17 November 1971, pp. 3-5, are superseded.

The CHILI implementation of LEAP should be completed by March 1973.

Implementation specifications for data structures and data operators, are due in December 1972, with full implementation together with the associated analysis routines by September 1973.

Analysis algorithms now exist for graphical syntax checking, determinacy, halting and termination, and repetition freeness. Those for control analysis, deadlock, resource allocation, and minimal performance analysis are due September 1973.

Except for a formal semantics and a corresponding attack on program correctness, which means proofs of algorithms, LOGOS will have LDP as a running representation and analysis system in September 1973.

It is anticipated that in 1974 the effectiveness of the LOGOS design environment will be evaluated by designing and implementing a small computing system having useful applications to government needs.

Though LOGOS is an open-loop system, the work of Professor Lynch and his group, defined as Total Optimal System Design in the Renewal Application, pp. 8-11 and Appendix C, could, in time, close it. This work will apply optimization techniques to LOGOS designs to produce optimal performances for specific, given purposes. The first-cut LOGOS target system design in 1974 will present opportunities for applications as the LOGOS system produces the performance data for the target system.

Sincerely,

E-L. Glaser

Edward L. Glaser
Principal Investigator

Project LOGOS Annual Report for 1 September 1970 to 31 August 1971

Sponsored by the Advanced Research Projects Agency

Department of Defense

ARPA Order No.: 1372

Program Code No.: 9D30

Contractor: Case Western Reserve University, Cleveland, Ohio 44106

Effective Date: 15 May 1969

Expiration Date: 31 August 1971

Amount: \$ 1,465,022

Contract No.: DAAB 03-70-C0024

This annual report is in letter form, as directed (ARPA Reporting Instructions, pp. 22-13, 14) and is respectfully submitted:

E. L. Glaser

E. L. Glaser
Principal Investigator

16 December 1971

The Director
Advanced Research Projects Agency
Department of Defense
1400 Wilson Blvd.
Arlington, VA 22209

Annual Report, Project LOGOS, 1970-71
Re: DAAB 03-70-C0024

Dear Sir:

As directed I render this annual report for 1970-71 in three copies under the above contract, full title of which is Computer-Aided Design and Certification of Computer Systems (Project LOGOS). This report covers the period from 1 September 1970 to 31 August 1971, for which the 5th through the 8th quarterly management reports were duly submitted.

A concise and factual discussion of technical findings and accomplishments for the report period follows:

1. Certain theoretic advances significantly increasing the capability of building a LOGOS design system turning out certifiable target systems were published as theses:

(a) Charles W. Rose, A System of Representation for General Purpose Digital Computer Systems. The thesis is developed that (1) there exists a graph-theoretic system of representation which is suitable for describing the structure and behavior of general purpose digital computer systems including those with parallel or concurrent capabilities; (2) that the representation is equally well-suited for describing hardware and software, and allows the integrated specification of computer systems; (3) that it provides insights to the designer of computer systems which aid him in positioning the hardware-software interface in target systems; (4) that the representation is amenable to algorithmic analysis and implementation of the target system; and (5) that there exists a corresponding internal representation, to which the external graph-theoretic model may be transformed, suitable for machine analysis and implementation of the model.

An environmental view of computer systems is introduced as the philosophical basis for the thesis, and a graph-theoretic realization of that philosophy is developed which support parts (1) - (4) of the thesis. An implementation of the representation is described which supports the contentions of part (5) of the thesis.

(b) Franklyn T. Bradshaw, Structure and Representation of Digital Computer Systems. The objective of this work is to further develop the discipline and tools used in the design of digital computer systems for which the logical behavior is completely known.

To design such computer systems, it is necessary to represent all logical aspects of the system. This is a task for which the direct solution of enumerating all states is impractical for systems of any complexity. To meet the representation requirements in full, a layered, hierarchical system structure is adopted in which, for conceptual consistency, system users may be regarded as the highest layer. System layers consist of facilities, each of which may be activated upon request to perform a computational service for a user. A facility activation is called a 'task', which becomes associated with the user for whom the service is being performed. The task may be directed by the higher layer user and may in turn activate facilities on lower layers to have subtasks performed. The lowest layer system consists of 'system primitives', those facilities whose tasks are no further, decomposed into subtasks.

In many situations, physical restrictions limit the number of activations of a given facility and the queueing discipline is required to cope with concurrent requests in excess of the established limit. The layered concept of system structure provides a natural setting from which to extract queueing theory models for use in system performance analysis.

Then, in the general case, the elements of each facility include physical resources, algorithms to direct the execution of a user task, and an enclosing control which is the interface with higher layer users and is itself an algorithm. Then a facility representation requires the representation of an algorithm, and for this the uninterpreted parallel schemata of Karp and Miller have been adopted and extended with the inclusion of procedure calls and BLOCK delimiters similar to ALGOL-60. The BLOCK concept is the vehicle whereby logical analysis of the total system becomes feasible.

Each algorithm is delimited by a BLOCKHEAD, BLOCKEND pair and is accessible in a well-defined manner through the BLOCKHEAD. Moreover, an algorithm may be regarded as a complex data operation, consisting of simpler operations, each of which may itself be a block. Then the determination of the logical correctness of a system may be conducted on a BLOCK by BLOCK, facility by facility, layer by layer basis. Within each BLOCK, the assumption is made that other nested BLOCKS, procedures called, and facilities activated are well-formed and hence regardable as a single complex operation. Having established the well-formedness of the given BLOCK, it may then be regarded as a single complex operator for the analysis of the other BLOCKS. The BLOCK technique makes practical tasks which by other techniques are impractical.

(c) Michael S. Pliner, PDMS--A Primitive Data Base Management System for Representing Structure Data in an Information Sharing Environment. This thesis describes the design philosophy and implementation of PDMS which represents a concerted effort to extend the concept of generalized data base management to applications where the data and operations to be performed on the data are complex and highly structured. To accomplish this goal, PDMS implements a basic, but extensible, set of primitive data management procedures which interface with systems programs or applications programs written in a variety of high-level pro-

gramming languages. The primitive procedure set has the capability of creating and saving a controlled access data base, providing for a definition and representation of a flexible and efficient class of data organizations within the data base, and providing a general set of data access and manipulation operations most of which are common to a wide range of applications including computer-aided design, information retrieval, and graphics processing.

The data management system operates as a time-sharing environment and provides for the construction and maintenance of common sharable data bases. This is accomplished by defining two classes of data bases. A data base can either be local (accessible to a unique user) or global (sharable among many users). A user or process can have one local and one global data base activated at any time and also have the capability of link and cross-reference structures between both data base files.

(d) Philippe de Rivet du Sabatier, Data Traffic Models for the Performance of Modular Computer Systems. A major problem in the design of computer systems is to determine the economic impact of each individual decision. The complexity of the system would, in general, appear to preclude any hope of handling the matter analytically. It is claimed here, however, that such an endeavor can be carried out successfully only if the structure of the systems obeys certain rules and, in particular, if it is modularly constructed and organized into a hierarchy of largely independent layers.

Within this framework, analytical methods derived mainly from queueing theory can be used to describe the relations existing between the workloads, and the corresponding response times of various subsystems, and of the entire system itself. More specifically, models are built for the different layers separately, each layer being assimilated, under carefully stated assumptions, to a priority class in a preemptive priority system. Global considerations are used to characterize the interrelationships between the workloads of these layers, and between the delays associated with their operation. The essential impact of the I/O activity is singled out, and a few I/O-related problems are studied in more detail as examples.

2. Pursuant to the LOGOS representation, structural, and data management systems, the capabilities of the PDP-10 computer system were upgraded with 41 million words of on-line disk storage as working memory, improved display equipment, etc., and the following installations were made or are in process:

(a) The representation system was installed on the PDP-10 in Stanford Artificial Intelligence Language (SAIL) for graphic manipulation and analysis of target system models. The fundamental algorithms for systems analysis of global structures were developed, and several were implemented. Debugging and integration of the system, however, were not completed in the report year.

(b) Imlac terminals were interfaced with the PDP-10 in a successful application of LOGOS structural principles.

(c) The primitive data management system (PDMS) was implemented on the PDP-10. PDMS now requires implementation of SAIL's LEAP constructs to provide two orders of magnitude increase in the flexibility and capacity of the associative data structures to be used in LOGOS programs--a task which ran beyond the report year.

(d) The editing system, due to Englebart and modified here, was found to require further, extensive modifications to fit PDMS, but this task was not completed in the report year.

(e) The syntax for data structure description and graphical representation was completed. Work began on the detailed description of data operators and memory hierarchy description.

(f) Methods of computer-aided hardware design developed in industry were studied. The conclusion was that the implementation of the primitive and atomic operator graphs of the LOGOS representation system in integrated circuit modules will be straightforward.

Although aspects of the work are from one to four months behind schedule (the LEAP constructs and the editing system for PDMS are examples), replanning and rescheduling are represented in the LOGOS Renewal Application dated 17 November 1971, pp. 3-5.

3. The work of the report year was also summarized in five papers given in the Primary Seminar on Project LOGOS, 27-28 October 1971 at Case Western Reserve University and repeated with additional information in a classified session for government personnel at the National Security Agency, 4-5 November 1971. More than 60 copies of the following papers were there distributed:

E. L. Glaser, Introduction and Overview of the LOGOS Program.

F. G. Heath and C. W. Rose, The Case for Integrated Hardware/Software Design with CAD Implications.

F. T. Bradshaw, Some Structural Ideas for Computer Systems.

C. W. Rose and F. T. Bradshaw, The LOGOS Representation System.

M. S. Pliner and C. W. Rose, A Primitive Data Base Management System for an Integrated Computer-Aided Design Facility.

4. The following figures represent expenditures for the report year:

(a) The amount funded was \$ 1,465,022.00.


(b) The amount expended at the beginning of the report year, namely up to 31 August 1970 was \$ 450,524.71. Of this, salaries were \$ 127,812.42, and nonsalary items were \$ 322,712.29.

(c) The amount expended at the end of the report year, namely, up to 31 August 1971 was \$ 989,196.64. Of this, salaries were \$ 339,229.50, and nonsalary items were \$ 649,967.14.

(d) Unexpended funds duly billed, then, were \$ 475,825.36 on the original contract which was effective 15 May 1969 to expiration on 31 August 1971. There were, however, unbilled expenditures (computer operating costs (\$ 445,173.20) and equipment commitments (\$ 76,000.00)) of \$ 521,173.20. This leaves a deficit on said contract of \$ 45,337.84 to be deducted from past PDP-10 operating costs, as agreed.

This annual report on Project LOGOS for 1970-71 is respectfully submitted:

Sincerely,

A handwritten signature in cursive script, reading "E. L. Glaser".

E. L. Glaser
Principal Investigator